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A PRELIMINARY REPORT

ON

THE UTILIZATION OF PETROLEUM AND NATURAL GAS IN WYOMING

BY

W. R. CALVERT

WITH A DISCUSSION OF

THE SUITABILITY OF NATURAL GAS FOR MAKING GASOLINE

BY

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A PRELIMINARY REPORT ON THE UTILIZATION OF PETROLEUM AND NATURAL GAS IN WYOMING.

By W. R. Calvert.

INTRODUCTION.

The presence of oil and natural gas in Wyoming has been known for a long time, and many more or less sporadic attempts have been made to develop these resources commercially, but owing to a number of factors, such as inadequate transportation facilities, lack of capital, and poorly advised prospecting, it has been only within recent years that Wyoming has taken other than a minor part in oil production. With the successful development of the Salt Creek field north of Casper, however, prospecting received a new and vigorous impetus, and at the present time many rigs are being operated at widely scattered localities in the endeavor to develop other equally remunerative territory. Gas has been discovered in the State in considerable quantity, notably in the Bighorn Basin, but owing to marketing limitations this resource has thus far not been utilized fully.

Unlike that of many other oil and gas producing regions the history of production in Wyoming has not been marked by large or excessive waste of either gas or oil. This exceptional feature is the natural result of local conditions, for there have been few instances where wells to producing sands have not been easy to control. The generally excellent quality of the oil produced has also been a factor in discouraging waste, for it is self-evident to the operators that any waste of oil means commensurate reduction in financial returns. In general the oil of Wyoming is of paraffin base and of low specific gravity, with a consequent large percentage of lighter distillation products. Conditions are therefore quite different from those prevailing, for instance, in those California or Gulf Coast fields where the oils have an asphaltic base.

Acting under instructions from the Director of the Bureau of Mines, the writer spent a part of the winter of 1912–13 in the field collecting data relative to the utilization of oil and natural gas in Wyoming, and supplemented that study by personal inspection of conditions in the California fields. The main purpose of this work was to ascertain what waste, if any, now accompanies the industry in Wyoming, and, if such waste were in evidence, to suggest means for its prevention. No attempt is made in this paper to discuss other than the commercial phases of the subject, as the geology of the fields and the yield of the wells have already been presented in various publications of the United States Geological Survey. As stated previously, the writer noted in Wyoming few instances of unnecessary waste of oil or gas; hence the present paper is rather a bare recital of conditions without related recommendations. Certain exceptions to this statement are, however, noted later in the text.

The writer desires to acknowledge the courtesy of various operators in the State, and he feels under especial obligation to Mr. Homer T. Lamb, of the Bighorn Oil & Gas Co., at Greybull, and to the representatives of the Midwest Oil Co. and of the Natrona Pipeline & Refining Co., at Casper. The refinery superintendent of the Midwest Oil Co., Mr. William Dietrich, also deserves special mention.

OIL AND GAS FIELDS IN WYOMING.

Commercial output of oil in Wyoming is to be credited mainly to four areas, of which the Salt Creek field north of Casper yields the greater proportion. The Byron field, in the northern part of the Bighorn Basin, furnishes oil for a small refinery at Cowley, a railroad station 4 miles from the wells. The Spring Valley field, in Uinta County, has been yielding oil in small amounts for a number of years. Near Lander a heavy asphaltic oil has until recently been delivered to the Northwestern Railroad for fuel, and there now seems reason to anticipate a moderate production of a light refining oil from adjacent territory. Small amounts of oil have been obtained from various other localities in the State—Douglas, Moorcroft, and Newcastle—but the production has not been of consequence.

The commercial utilization of natural gas in Wyoming has been thus far practically confined to the Greybull field, which supplies illuminant to Greybull and to the town of Basin, 6 miles distant from the field. Large amounts of gas are presumably obtainable in the Byron field, one well yielding over 6,000,000 cubic feet daily, but a market has not been found. Gas is associated with the oil of the Spring Valley field, but in small amounts, and the entire supply can be used locally for development work. Gas is present also at Douglas, but the wells are capped. The heavy asphaltic oils at Lander are accompanied by some gas, part of which has been utilized locally for drilling purposes. A gas well of large production has been reported from the Oregon Basin, a topographic depression in the western part of the Bighorn Basin. The utilization of the oil and gas of these various areas is considered separately on the following pages.

UTILIZATION OF WYOMING OILS.

SALT CREEK FIELD.

About 40 miles due north of Casper is an oil-producing area known as the Salt Creek field, the name being derived from the main stream of the district. The presence of oil in this locality as springs or surface seeps was probably known prior to 1880, and the first wells were drilled in 1889. By 1893 oil was hauled by wagon to Casper, but the production was necessarily small. The first well to reach the lower sand was not drilled until the fall of 1908, and it was not until 1910 that the development of the oil resources was undertaken on a scale commensurate with the value of the field, when the Midwest Oil Co., representing French and Colorado capital, acquired holdings. This company erected a refinery at Casper and connected it with the field by a pipe line. A smaller organization, known as the Natrona Pipeline & Refining Co., also erected a refinery, which was likewise connected with the field. In December, 1912, the Midwest refinery capacity was about 4,000 barrels of crude daily, and about 1,000 barrels a day passed through the Natrona plant. Several months later the Midwest company took over by lease the holdings of the Natrona organization, and at present is in complete control of the refining of the oils. The capacity of each plant is to be increased, for heretofore the Midwest company has been unable to refine the product of all of its wells and about half of them have been capped. The Midwest refinery is equipped with 9 crude stills, 6 of which have a capacity of 850 barrels each a day, and 3 a capacity of 525 barrels each, when operated as a skimming plant. An addition to this refinery is in course of construction and will include six 850-barrel crude-oil stills. The present refinery has a storage capacity for crude oil of about 220,000 barrels. The tanks are about three-quarters of a mile from and 40 feet above the refinery, so that the oil flows by gravity to the crude stills. Oil is brought to the storage tanks through a 6-inch line from the field, there being a pumping plant near the wells and another midway between the field and the tanks.

No attempt is made at either refinery to make other than simple cuts in refining, and the usual products comprise gasoline, illuminating and gas oils, and fuel-oil residuum. At times the demand for the fuel-oil residuum is so insistent that the refineries have been operated as skimming plants; that is, only the benzine and naphtha are distilled and the remaining product is used as fuel. This procedure, is, of course, not adopted except when rendered imperative in order to fulfill the terms of contracts for fuel oil.

At present there is practically no waste in handling the crude oil in the Salt Creek field, although formerly less care was taken at the wells. There is, however, certainly an economic loss in using as fuel oil the residuum below the gas-oil cut, containing as it does valuable constituents for lamp oils, lubricating oils, and waxes. The oil should be completely refined.

In the Salt Creek field two distinct types of oil occur—one from a sandstone designated the Wall Creek, and the other from a stratigraphically higher sandstone termed the Shannon. The oil from the former is dark-green in color, brownish-red by reflected light, and has a specific gravity of 0.8252 at 15° C. (31.7° B. at 60° F.). The Shannon oil is of a slightly lighter hue, and the color by reflected light is not so pronounced. Its specific gravity is 0.9071 at 15° C. (24.4° B. at 60° F.). Both oils tend to congeal under lowering temperatures, though the Shannon oil possesses this characteristic to the greater degree. No especial difficulty is experienced during the winter months in piping the lighter oil, but that from the Shannon sandstone is apt to clog. Little of the latter has been piped out of the field, however, and at the time of the writer's visit it was being stocked in a 15,000-barrel storage tank near the wells.

For the purpose of comparison the analyses of the Wall Creek and Shannon oils of the Salt Creek field are given below, and an analysis of the fuel oil marketed from the Midwest refinery is also shown. These analyses were made in the petroleum laboratories of the Bureau of Mines at Pittsburgh, Pa., from samples collected by the writer.

Analyses of oils from the Salt Creek field.

[A. S. Crossfield, analyst.]

	Wall Creek sandstone.	Shannon sandstone.	Fuel oil.
Laboratory No.	948	950	949
Specific gravity at 15° C.	0.8250	0.9071	0.9010
Distillation, atmospheric pressure:	*Per cent.*	*Per cent.*	*Per cent.*
0° to 150° C.	3.4	0.0	0.0
150° to 175° C.	5.7	.0	.0
175° to 200° C.	2.5	.0	.0
200° to 225° C.	4.8	.0	.0
225° to 250° C.	6.3	.0	.0
250° to 275° C.	6.0	.0	.0
275° to 300° C.	5.9	[b] .4	.0
300° to 325° C.	[a] 7.1	[b] 1.9	.0
Distillation, 10 mm. of mercury, vacuum:			
150° to 175° C.	[c] .5	[b] 3.2	[c] 1.7
175° to 200° C.	[c] 2.6	[b] 4.6	[c] 2.3
200° to 225° C.	[c] 5.5	[b] 8.7	[d] 6.4
225° to 250° C.	[e] 6.3	[b] 12.4	[e] 13.9
250° to 275° C.	[f] 4.8	[g] 11.0	[e] 13.6
275° to 300° C.	[h] 6.1	[e] 9.6	[i] 10.9
300° to 325° C.	[h] 7.9	[e] 11.9	[i] 11.8
Residue	[j] 19.9	[j] 34.7	[j] 39.0
Water	.7	.9	.0
Loss	4.0	.7	.4

Remarks.—Laboratory No. 948. Sec. 25, T. 40 N., R. 79 W., Salt Creek field, Natrona County, Wyo. Owned by Midwest Oil Co. Sample taken from line leading to field storage tank. Sampled by W. R. Calvert, Dec. 31, 1912.

Laboratory No. 950. Shannon well No. 1, Natrona County, Wyo., Salt Creek field. Owned by Franco-American Oil Co. Sampled by W. R. Calvert, Dec. 31, 1912.

Laboratory No. 949. Fuel oil, Midwest Oil Co. Sampled by W. R. Calvert, Dec. 31, 1912. Crude is refined, removing gasoline, kerosene, and gas oil. Sample is residue.

[a] Solid with crystalline paraffin at −10° C.

[b] Contains no crystalline paraffin at −13° C.

[c] Contains much paraffin.

[d] Crystalline paraffin separates at 14° C.

[e] Solid with crystalline paraffin at 0° C.

[f] Crystalline paraffin separates at 24° C.

[g] Contains some crystalline paraffin at −13° C.

[h] Solid with crystalline paraffin at 24° C.

[i] Solid with crystalline paraffin at 23° C.

[j] Contains much vaseline and paraffin.

An analysis of the crude refined by the Midwest Oil Co., made in the refinery laboratory at Casper, has been furnished by the superintendent, William Dietrich. This analysis is as follows:

	Per cent.
Gasoline	18. 92 at 62° B.
Naphtha	2. 75 at 52° B.
Kerosene	24. 00 at 43° B.
Mineral seal	3. 00 at 37° B.
Gas oil	17. 50 at 35° B.
Wax oil	15. 00 at 30° B.
Tar	16. 00
	97. 17
Loss	2. 83
	100. 00

From the foregoing analyses it is evident that the oil from the Wall Creek sand of the Salt Creek field is a valuable product. The Shannon crude is essentially a lubricating oil, and as such it has more value, barrel for barrel, than that now refined. According to Irving C. Allen, petroleum chemist for the Bureau of Mines, sample 948 would have a value of about $2.25 per barrel on the basis of comparison with the prevailing price ($2.50) of similar Pennsylvania crude, and the value of samples 949 and 950 would have, on the same basis, a value in excess of $2.28 per barrel. These crudes have no rational place in fuel oils. Scientific and proper methods of refining are most important if most efficient use of crude materials is desired. These crudes have a high value for the preparation of refined products. They should not be used as fuel. The Salt Creek and Byron oils are high-grade refining oils. Practically no use has been made thus far of the Shannon oils, for the reason that the available production is much less than that from the Wall Creek sand. Wells drilled in the Shannon sand are small producers, averaging about 3 barrels a day. Wells in the Wall Creek sand or some in the associated shale, may come in with an initial daily production in excess of 1,200 barrels, and settle down to a 200-barrel production.

BYRON FIELD.

In the northern part of the Bighorn Basin, 15 miles south of the Montana-Wyoming State line, is a small area where oil is produced commercially. This is designated the Byron oil field, as the wells are near the town of Byron. The Billings & Montana Oil Co. operates in this field, and its wells supply crude to a refinery at Cowley, a railroad station 5 miles to the north. This refinery has a capacity of 160 barrels a day. The normal yield of the wells is more than sufficient to supply the refinery, and it is necessary to pump them only part of the time. As at the Midwest refinery at Casper, the products comprise gasoline, kerosene, gas oil, and fuel-oil residuum. Until recently some difficulty was experienced in marketing the last-named product, but in January the stock was practically exhausted.

In physical character the Byron oil is a thin liquid, brownish red by transmitted light, and olive green in reflected light. The specific gravity is 0.8174 at 15° C., or about 42° B. Following is an analysis of the Byron crude made in the laboratory of the Bureau of Mines from a sample obtained on the E. E. Jones lease, No. 5 well:

Analysis of oil from the Byron field.

[A. S. Crossfield, analyst.]

Laboratory No	951
Specific gravity at 15° C	0.8174
Distillation, atmospheric pressure:	*Per cent.*
0° to 150° C	4.7
150° to 175° C	10.6
175° to 200° C	13.4
200° to 225° C	8.7
225° to 250° C	[a] 7.2
250° to 275° C	[b] 8.0
275° to 300° C	[c] 7.8
Distillation, 9 mm. of mercury, vacuum:	*Per cent.*
150° to 175° C	[d] 1.5
175° to 200° C	[d] 2.5
200° to 225° C	[e] 4.0
225° to 250° C	[f] 4.8
250° to 275° C	[f] 4.9
275° to 300° C	[g] 3.4
300° to 325° C	[g] 3.5
Residue	4.7
Water	.0
Loss	2.3

[a] Contains no crystalline paraffin at −15° C.

[b] Contains some crystalline paraffin at −15° C.

[c] Solid with crystalline paraffin at −15° C.

[d] Contains no crystalline paraffin at −13° C.

[e] Solid with crystalline paraffin at −10° C.

[f] Solid with crystalline paraffin at 0° C.

[g] Solid with crystalline paraffin at 23° C.

SPRING VALLEY FIELD.

The Spring Valley oil field is situated in Uinta County, southeast Wyoming, the name being derived from that of a station on the Union Pacific Railroad, which passes not far to the south of the producing area. Development, more or less sporadic, has been in progress here since 1902, and there are five companies at present in the field. Production has never been large, seldom amounting to more than 200 barrels per day. The wells are of small individual capacity, and it is necessary to pump practically from the time they come in, except occasionally when, after capping, the gas pressure accumulates to such a degree that the oil is ejected on release of pressure. Oil produced in this field is piped to the loading station on the railroad through the line of the Pittsburgh-Salt Lake Oil Co. and shipped to the plant of the Utah Oil Refining Co. at Salt Lake City. The president and general manager of the latter company, J. C. Howard, has furnished the following information relative to this particular oil:

> The crude in the Spring Valley field, as received at our plant, runs about 39.5° to 41° B.,[a] and has a light-green color, though in the neck of a 4-ounce bottle it appears to be red. It is a "sweet" crude oil without any perceptible trace of sulphur. It produces about 16 per cent of gasoline (62° B.),[b] 35 per cent of water-white kerosene (43° B.),[c] 10 per cent of paraffin gas oil (35° B.),[d] and contains 6.6 per cent of wax,

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[a] Specific gravity, 0.8260 to 0.8187.

[b] Specific gravity, 0.7292.

[c] Specific gravity, 0.8092.

[d] Specific gravity, 0.8485.

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of which we are able to recover 3½ to 4 per cent when run through our presses. In the crude scale form the melting point of this wax is about 124° to 126° F., and is not quite as high as that of the Pennsylvania wax. The crude also yields 15 per cent of engine oil, having a specific gravity of 28° B.,[a] a flash point of 400° F., a viscosity of 230 at 70° F., and 10 per cent of green cylinder stock having a specific gravity of 19° to 20° B.,[b] a flash point of 540° F., and a viscosity of 190 at 212° F. On account of the crude containing about 1½ per cent of asphalt or tarry matter, this cylinder stock, which represents about 10 per cent of the residuum left in the still, contains virtually all the tarry matter of the crude, and when reduced in the cylinder stock would amount to 15 per cent.

LANDER FIELD.

The Lander oil field is situated on the northeast flank of the Wind River Mountains, in Fremont County, not far from the town of Lander. The first drilling was done in 1885, when three wells, having a reported yield of 200 barrels each, were brought in. According to the Wyoming State geologist the output of the field in 1911 was about 350 barrels daily, but at the time of the writer's visit to the field in December, 1912, production was limited to a small amount used locally, and the wells were capped. This nonuse resulted from inability to renew a former fuel contract with the Northwestern Railroad.

Two distinct types of oil occur in the Lander field. The bulk of past production was of black asphaltic oil with a specific gravity between 0.9198 and 0.9091 (22.2° and 24° B.). From a horizon stratigraphically higher an oil, olive green by reflected and wine color by direct light, has been obtained. The specific gravity of this oil is 0.8121 (42.4° B.[c]) Thus far the production of this latter oil has come from one well, but active development is forecasted for 1913. No samples of either oil were taken by the writer, hence analyses are not given.

OTHER LOCALITIES.

Oil is found in Wyoming at many localities other than those previously described, but up to date the amount produced in any one has not been of especial commercial importance. Several wells on La Prele Creek, 14 miles west of Douglas, have disclosed an asphaltic oil of low gravity, but practically no use of it has been made. Northeast of Moorcroft, in Crook County, small amounts of similar oil have been found and prospecting is active. At this locality is an oil spring from which lubricant was hauled to the mines in the Black Hills in the early days. Some asphaltic oil has been obtained from the vicinity of Newcastle, but there have been no developments of late.

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[a] Specific gravity, 0.8861.

[b] Specific gravity, 0.9396 to 0.9 93.

[c] Woodruff, E. G., and Wegemann, C. H., The Lander and Salt Creek oil fields, Wyoming: U. S. Geol. Survey Bull. 452, 1911, p. 29.

THE UTILIZATION OF WYOMING NATURAL GAS.

GENERAL STATEMENT.

The total aggregate production of natural gas in Wyoming is very small compared with that of certain other States, such as West Virginia, Oklahoma, Kansas, Louisiana, or California. As a matter of fact, gas is a commercial factor at only one locality in Wyoming, though it accompanies the oil in several fields and is used there locally by operating oil companies for domestic and camp purposes. This relative nonuse of the gas resources is due mainly to market conditions, for sparse settlement and absence of manufacturing interests combine to cause lack of demand. The natural-gas industry is therefore in an embryonic stage of development. With an adequate supply assured there seems reason to hope for its utilization by commercial industries having need of this ideal source of heat and power, but awaiting such actual assurance no immediate market for large quantities exists. The analysis of at least one gas sample collected by the writer suggests that its conversion into gasoline is a possibility worth consideration, and that the installation of a compressing plant such as has been found applicable in the case of certain California natural gas and gas in other States will serve to render valuable commercially a product now wasted in the field.

GREYBULL FIELD.

Gas was discovered in a well drilled July, 1907, by Messrs. Minor and Sherard, not far from the town of Greybull. It came in under pressure and with a reported volume of 6,000,000 cubic feet a day. Seventeen months later the well was still open and the gas volume had decreased to 1,000,000 cubic feet. Five months later the well was capped, and in December, 1912, was making no gas. In 1907 a company, known as the Bighorn Oil & Gas Co., was organized to put gas on the market at Greybull and at the town of Basin, some 6 miles distant. This company has laid mains in both towns and connected them with the field. A number of wells were drilled that obtained gas, and the outlines of the field determined by 13 dry holes. The producing wells are all connected, and care is taken to see that those of higher pressure do not cause a back pressure on the others. In 1908 the average rock pressure is reported to have been 120 pounds, in 1909, 100 pounds, and in December, 1912, to have decreased to 30 pounds. In August, 1912, the combined capacity of the 8 producing wells was tested at 1,460,000 cubic feet, but at the end of December, 1912, it was only 800,000 cubic feet. Obviously, therefore, the production of the field has lessened greatly, but that the rate of decrease will continue is, of course, problematical. There is no doubt, however, that the failure to close promptly the first

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well drilled was highly detrimental to the field, for the amount of gas thus wasted would have supplied the present demand at Greybull and Basin for a period of 24 years. The present operating company is adopting every precaution to conserve and utilize fully the gas now available, but in spite of this care signs point to an exhaustion of the field before many years, due primarily to the inability or negligence of the first operators to control their well.

The gas of the Greybull field is of high quality, as attested by the following analyses, made at the experiment station of the Bureau of Mines at Pittsburgh, Pa., of samples collected by the writer:

Analyses of natural gas from Greybull.

[G. A. Burrell, analyst.]

	Lab. No. 3224.	Lab. No. 3222.
Density (air=1)	0. 64	0. 77
	Per cent.	*Per cent.*
CO_2	. 20	. 00
O_2	. 00	. 00
CH_4	81. 70	51. 55
C_2H_6	17. 35	47. 20
N_2	. 75	1. 25
Claroline absorption, per cent	26	22. 60
Gross heating value, at 0° C. and 760 mm. pressure, B. t. u	1,192	1,427

Laboratory No. 3224 is from the Island No. 1 well, one of the 8 producing gas commercially. The initial production of this well was 750,000 cubic feet at a rock pressure of 120 pounds. The volume was not ascertained at the date of the writer's visit, but the pressure has decreased to 30 pounds.

Laboratory No. 3222 is a sample of casing-head gas from a nonproducing well in which some oil was found, the object being to ascertain the difference, if any between this "wet" gas and that from the "dry" gas wells. As shown by the analyses, considerable variation exists. The composition of the gas represented by sample No. 3224 is practically identical with the composition of the natural gas supplied to Pittsburgh, Pa., according to analyses made by Burrell.

In connection with the foregoing and following gas analyses it should be stated that a uniform method of sampling was adopted. Samples were collected in duplicate, using patent-stoppered pint bottles. A glass tube of three-tenths inch internal dimension was connected with the orifice from which the gas was allowed to escape, either by being placed directly over the nipple, where one was available, or by using a tightly rolled paper cone. The free end of the tube was then inserted to the bottom of the sample bottle and gas allowed to pass in freely for a period of five minutes in order to replace the air completely. The bottle was then withdrawn slowly and the gas allowed to blow directly into the bottle mouth while the stopper was snapped into place. The absence of oxygen in the gas samples, as determined by analysis, demonstrates that this method may be applied successfully.

BYRON FIELD.

Reference has already been made in this paper to oil in the Byron field. Development in this area thus far shows that there is one district where oil, accompanied by some gas, occurs, and another where gas alone is found, though in the latter district the strata underlying the gas horizon have not been tested. The Utah-Wyoming Consolidated Oil Co. has holdings in this latter area and has one well testing over 6,000,000 cubic feet of gas a day, at a reported rock pressure of 600 pounds. A second well is now (June 1, 1913) down to within a few feet of the pay sand, and has been awaiting equipment to control the anticipated flow of gas.

Shortly after the writer's visit to the field the producing well was connected with the near-by village of Byron by a 3-inch line. Because of the high pressure at the well the orifice leading into the main line was stopped down to one-half inch, and even that diameter allowed insufficient decrease in pressure at Byron for the best results for burning in mantles. The writer was unable to obtain a sample of gas from the high-pressure well, but a sample of casing-head gas was collected from one of the oil wells. This gas is used at the pumping station for heating and lighting. Following is an analysis of this gas:

Analysis of natural gas from Byron.

[G. A. Burrell, analyst.]

	Lab. No. 3220.
Density (air=1)	0. 68
	Per cent.
CO_2	. 47
O_2	. 00
CH_4	64. 05
C_2H_6	32. 28
N_2	3. 20

Claroline absorption, 18.2 per cent.

Gross heating value, 1,282 B. t. u. at 0° C. and 760 mm. pressure.

In the lack of an analysis of the gas from the gas well proper, no definite statement can be made regarding the adaptability of the gas for gasoline manufacture. However, the fact that it is under high pressure and that the gas accompanying the oil in the same field is not suitable for gasoline suggests that the gas from the high-pressure well is adapted only for use as fuel and illuminant.

SALT CREEK FIELD.

Practically all of the oil from wells drilled into the Wall Creek sandstone of the Salt Creek field comes in with considerable pressure, and gas accompanies the oil constantly. No gas of consequence is associated with the oil from the Shannon sandstone. The gas of the field is used locally for drilling, for pump boilers, and for domestic purposes, but the supply exceeds all demands for the uses mentioned. Exact data as to the amount of gas utilized were not obtainable. A rough estimate suggests that a half million cubic feet was being used a day by the Midwest Oil Co., and that an equal quantity escaped into the air. The capped wells of the Midwest Co. would probably yield another million feet. The Franco-American Co. was using gas from only one of its wells, the supply being ample for all its needs, and at least a half million feet was not utilized. No local market exists for this gas, as the field is over 40 miles distant from Casper, the nearest town, and the demand there would hardly be sufficient to warrant the piping of gas from the wells. The analysis of one gas sample collected by the writer from the line at the Midwest camp suggests that the gas could be utilized for the manufacture of gasoline. Of course, it is realized that two wells in the same field, and even in close proximity to each other, may yield gas noticeably unlike; hence one analysis does not furnish sufficient evidence to warrant a prediction as to the suitability for gasoline making of all gas from different wells in the same field. However, the excellent character of the gas as shown by the following analysis suggests that this resource in the Salt Creek field has commercial possibilities for gasoline and that the lack of a local market for its consumption in the gaseous form need not justify its nonutilization.

Analysis of natural gas from the Salt Creek field.

[G. A. Burrell, analyst.]

	Lab. No. 3225.
Density (air=1)	0. 96
	Per cent.
CO_2	. 00
O_2	. 00
C_2H_6	60. 40
C_3H_8	10. 63
N_2	28. 97

Claroline absorption, 31.9 per cent.

Gross heating value, 1,437 B. t. u. at 0° C. and 760 mm. pressure.

OTHER LOCALITIES.

Aside from the three fields discussed in the preceding pages there are no other areas in Wyoming to which special interest attaches because of natural-gas development. A number of wells have been drilled and gas obtained in what is known as the Douglas field. No commercial use has been made of the gas, however, and the wells are capped. Some gas accompanies the oil of the Lander field, but any surplus over the amount used in the field itself is not sufficient to consider its nonuse a real waste. Similar conditions hold with respect to the Spring Valley field. Some gas has there been used for drilling, but the total amount available is inconsiderable. It will be seen, therefore, that the development of the natural gas resources of Wyoming has been largely incidental to oil production, and that no deliberate waste of the product is now to be found within the State.

THE SUITABILITY OF NATURAL GAS FOR MAKING GASOLINE.

By George A. Burrell.

INTRODUCTION.

In almost every oil-producing State in the Union gasoline is being extracted from the natural gas that accompanies the oil. In Wyoming the oil developments are yet in an embryonic stage so that installations for the production of gasoline from natural gas have not been made, but there is no reason to believe that Wyoming natural gas will not in time contribute to the gasoline production of the country. Hence a brief description is here given of the more important factors that must be taken into consideration in the erection of plants for obtaining gasoline from natural gas. The method of plant operation described in this paper is that generally used throughout the country. Some plants differ in detail and at a few plants processes embodying arrangements that differ considerably are used. No attempt is made in this paper to describe the operations in detail.

GROWTH OF THE INDUSTRY.

A statement by David T. Day, published by the United States Geological Survey,[a] shows that in the year 1911 about 7,500,000 gallons of gasoline was produced from natural gas in the United States. Day believes this estimate to be low. The writer recently made an extended investigation of this industry in Oklahoma and found during May, 1913, that 23 plants produced about 400,000 gallons of natural-gas gasoline. There were about 25,612 producing oil wells in Oklahoma at the end of May. At only about 300 wells was casing-head gas being utilized to make gasoline. The writer estimates that the value of the recoverable gasoline escaping as gas in Oklahoma is 10 per cent of that of the crude oil produced. These figures indicate the possible value of the gasoline obtainable from the natural gas in one State and show why the possibilities of Wyoming natural gas should be given careful attention.

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[a] U. S. Geol. Survey Press Bull. 77, October, 1912.

GASOLINE VAPORS IN NATURAL GAS.

Gasoline contains those members of the series of paraffin hydrocarbons that are liquid at ordinary temperatures.

Such members as concern one interested in the utilization of natural gas are mentioned in the accompanying table, which gives some of their characteristics:

Properties of the paraffins ordinarily present in natural gas and gasoline.

Name of paraffin.	Formula.	Boiling point.[a]	Specific gravity at 760 mm. and 0° C. (air=1).	Weight of 1 liter (45 °C., sea level).	Heating value per cubic foot at 0° C. and 760 mm.[b]
				Grams.	*B. t. u.*
Methane	CH_4	−160° C.	0.5544	0.7159	1065
Ethane	C_2H_6	− 93° C.	1.0494	1.3567	1861
Propane	C_3H_8	[c] − 45° C.	1.5204	1.9660	2654
Butane	C_4H_{10}	1° C.	2.0100	2.5940	3447
Pentane	C_5H_{12}	36.4° C.	....	....	4250
Hexane	C_6H_{14}	68.9° C.	....	....	5012
Heptane	C_7H_{16}	98.4° C.	....	....	....

Name of paraffin.	Illuminating value.	Liquefaction point.	Calculated volume of gas (at 60° F. and 30 in. pressure) from 1 gal.	Theoretical volume of air necessary to burn 1 cubic foot of gas.
	British candle power.	*° C.* *Lbs. per sq. in.*	*Cubic feet.*	*Cubic feet.*
Methane	[d] 5.0	−95.5 at 735[e] −81.8 at 807[f]	....	9.57
Ethane	[g] 35.0	35.0 at 664[e]	53	16.75
Propane	[g] 53.9	97.0 at 647[f]	45	23.92
Butane	....	....	37	31.10
Pentane	....	....	31	38.28
Hexane	....	....	27	....

[a] Holleman, A. F., Organic chemistry, 1910, p. 41.

[b] Landolt and Börnstein, Physikalish-chemische tabellen, 3d ed., pp. 416, 425 (determination by J. Thomsen).

[c] Other authorities give −17° C.

[d] Wright, L. T., Jour. Chem. Soc., vol. 47, 1885, p. 200.

[e] Landolt and Börnstein, op. cit., p. 185 (determination by Dewar).

[f] Landolt and Börnstein, op. cit., p. 185 (determination by Olszewski).

[g] Frankland, P., Jour. Chem. Soc., vol. 47, 1885, p. 235.

It will be noticed that the first four hydrocarbons—methane, ethane, propane, and butane—are gases at ordinary temperatures. The first two, methane and ethane, predominate in natural gas that issues under considerable pressure and is used for lighting and heating cities. Small quantities of propane and butane also exist in such natural gas, also some of the vapors of the gasoline liquids, pentane, hexane, and heptane, but not enough to make the natural gas valuable for gasoline production. Temperatures low enough and pressures high enough to keep methane in the liquid condition in the earth have not been found in wells, but all of the other paraffin hydrocarbons mentioned in the table may occur as liquids or vapors in the earth, and the three last named are, of course, always found as liquids. At ordinary temperatures and under a pressure of 635 pounds to the square inch ethane is liquified, and in the earth under less pressure it is a gas. Propane is more easily liquefied than ethane and butane more easily than propane. The last two, in the case of casinghead gases that are used for gasoline manufacture and are usually drawn from the wells under reduced pressure, are gases. The "permanent" gases as they issue from the wells are accompanied by more or less of the liquids in the form of vapor, just as water vapor exists in the atmosphere. The quantity of water vapor carried in air depends principally upon the temperature of the air, although pressure has some effect. Similarly, the proportion of vapor that accompanies the permanent gases issuing from a well depends on the temperature and pressure in the well. Other factors that affect the proportion of vapors present are the proportion of gasoline or lighter fractions in the oil and the intimateness of contact between oil and gas in the underground reservoirs.

PLANT OPERATION.

The natural gas used in many plants for gasoline manufacture is drawn from wells as much as 4 miles distant, and the number of wells supplying gas may be 50 or more. The reduced pressure under which the gas is drawn from the wells may be equivalent to 25 inches of mercury.

The treatment of the gas in the gasoline plant consists in compressing it to 25 to 50 pounds per square inch and passing it through cooling coils made of 2-inch pipe on which water at ordinary temperature is sprayed. At some plants the coils are immersed in tanks. Some liquid constituents are recovered at this stage of the process, but the quantity is comparatvely small. The residual gas from the first compression is subjected to pressures as high as 350 pounds per square inch, and then cooled in the same manner as before. The greatest amount of liquid that is obtained after the second compression and cooling may range from 1½ to 4 gallons per 1,000 cubic feet of gas treated. The liquid is received in tanks under heavy pressure. For marketing it is withdrawn and usually mixed with low-grade refinery naphthas.

In the operations described several changes occur in the gas, such as condensation of vapor, liquefaction of gas, and solution of some permanent gases in the liquid produced. That chemical changes occur—that is, a "cracking" of paraffin hydrocarbons at the temperatures and pressures used—is unlikely. The liquid collected in the receiving tanks may be very volatile, "wild," as it is called by the trade, and range in specific gravity from 0.676 to 0.582 (77° to 110° B.); consequently there is a considerable loss when it is exposed to the

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air. This loss may range from 10 to 50 per cent or more of the original liquid. Blending of the material with the refinery naphthas should be performed rapidly and as soon after manufacture as possible.

TESTING NATURAL GAS FOR GASOLINE CONTENT.

Natural gas is divided according to popular classification into "dry" gas, or that from which gasoline can not be extracted on a commercial scale, and the so-called "wet" gas, or that from which gasoline can be utilized, as described. There is, however, no sharp line of demarcation between "dry" and "wet" gas. The driest "dry" gas is that containing methane as the only combustible gas. Such gas issues from marshy beds and is found in regions where oil is not encountered, but is of rare occurrence in the oil fields. Next in order may be mentioned the natural gas that occurs in oil fields but is not associated with oil. It contains methane as the predominating paraffin hydrocarbon, but also contains higher members of the paraffin series. Such natural gas yields a liquid, "drip," as it is called, in the pipe lines, especially in the winter time, but is not rich enough in the higher hydrocarbons to be of commercial consequence for gasoline production. Natural gas, such as is supplied to Pittsburgh, Pa., Cleveland, Ohio, and other cities is of this general character. Finally may be mentioned the so-called "wet" gas, associated with oil, from which gasoline in commercial quantities can be obtained.

Throughout this paper the term "gasoline" is loosely used, as it is in the trade. Liquids having a specific gravity of 0.737 (59° or 60° B.) are largely sold as gasoline to-day, but liquids having greater and less densities are also utilized for the purposes for which gasoline is used. The specific gravity of so-called natural-gas gasoline may be as low as 0.58 (110° B.) A great loss by evaporation of course follows the handling of such gasoline.

TESTING NATURAL GAS FOR GASOLINE.

Proper testing of casing-head or other gas for gasoline production is important. At present the methods used include determination of the specific gravity of the gas, of its solubility in claroline oil, kerosene, alcohol, or olive oil, and of its combustion analysis, and its testing at the well with a small outfit consisting of a gas meter, gas engine, and compressor.

The writer knows of natural gases having as low a density as 0.81 (air = 1) from which gasoline is extracted. Gases ranging as high as 1.64 in density have been tested. Actual testing of the gas by means of a small portable outfit is always desirable. In drawing conclusions from the density determination it should be remembered that the presence of considerable nitrogen or carbon dioxide in the gas mixture would vitiate conclusions if their presence were not taken into consideration. Most natural gas contains the paraffin hydrocarbons in such large percentage that the density of the gas may be considered as being affected almost entirely by the proportions, but there are some exceptions. The paraffin hydrocarbons increase in density with ascension in the series; hence the density determination gives one an idea of the nature of the paraffins present.

Gasoline is also being extracted from natural gas that has as low an absorption percentage as 30 (absorption in claroline oil). The test of solubility is made by shaking 100 c. c. of the gas with the oil until the absorption is constant. Shaking 100 c. c. of the gas with 50 c. c. of alcohol gives about the same result.

QUANTITY OF GAS AVAILABLE.

Aside from the quality of the gas, the quantity available is a vital consideration. The writer knows of a few plants that are operating on as little as 40,000 cubic feet of gas daily, but the plants are largely experimental. The successful plants are utilizing at least 125,000 cubic feet. Tests of the quantity of the gas are usually made by means of a Pitot tube. If the portable outfit already mentioned is available the meter that accompanies the outfit is used for the gas measurements.

VARIATION IN GAS.

Before a plant is built, each well on the lease or adjoining leases should be carefully tested for quality and yield of gas. Different wells in the same lease may produce little or no gas or as much as 500,000 cubic feet daily. One well may yield gas of excellent quality, whereas another may yield gas that is practically worthless for gasoline manufacture.

RESIDUAL GAS.

The residual gas left after the gasoline has been extracted is frequently returned to the wells to be used in gas engines for pumping. At some places it is run into gas mains and used for town supply. The residual gas is of higher heating value than the natural gas used in Pittsburgh, Cleveland, and other cities. At some plants air leaks into pipe connections between the plants and wells so that the residual gas, which contains this air, has justified complaints that residual or "stripped" gas does not work well in gas engines. Residual gas should be frequently analyzed for oxygen, and all connections should be kept tight.

COST OF PLANT OPERATION.

A single-unit plant, consisting of two gas compressors, gas engines, piping, cooling coils, storage tanks, housing, etc., costs about $9,000 or $10,000, and will handle at least 500,000 cubic feet of gas. Two men, a day and a night engineer, can care for it. Interest on investment, depreciation, plant upkeep, accidents, etc., are, of course, other factors to be considered. Some of these will vary widely. The returns on the investment are, however, large. The ready disposal of the gasoline—that is, the shipping facilities available—is, of course, a vital consideration.

INFERENCES REGARDING WYOMING NATURAL GASES.

Of the gases whose analyses are shown in this paper, one, seemingly the richest in gasoline vapor of the several examined, is worthy of further investigation as regards its commercial possibilities. It has a density of 0.96 (air=1), but this is in part due to its containing much nitrogen, a worthless constituent. If the nitrogen were replaced by an equivalent quantity of ethane and propane, the density of the gas would, of course, be higher. It should be added that the gas analyses in the table give the percentage of the two predominating paraffin hydrocarbons only. Other gaseous paraffin hydrocarbons or gasoline vapors present are not shown, but the higher the gaseous paraffins, as shown by analyses, the higher usually is the gasoline-vapor content. The analyses give absolutely no indication of the possible value of other natural gas in the Wyoming oil fields.

Methods of testing natural gas are described in detail in Bulletin 42[a] of the Bureau of Mines.

PUBLICATIONS ON PETROLEUM TECHNOLOGY.

The following Bureau of Mines publications may be obtained free by applying to the Director, Bureau of Mines, Washington, D. C.:

BULLETIN 19. Physical and chemical properties of the petroleums of the San Joaquin Valley, Cal., by I. C. Allen and W. A. Jacobs, with a chapter on analyses of natural gas from the southern California oil fields, by G. A. Burrell. 1911. 60 pp., 2 pls., 10 figs.

BULLETIN 65. Oil and gas wells through workable coal beds; papers and discussions, by G. S. Rice, O. P. Hood, and others. 1913. 101 pp., 1 pl., 11 figs.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 10. Liquefied products from natural gas; their properties and uses, by I. C. Allen and G. A. Burrell. 1912. 23 pp.

TECHNICAL PAPER 25. Methods for the determination of water in petroleum and its products, by I. C. Allen and W. A. Jacobs. 1912. 13 pp., 2 figs.

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[a] Burrell, G. A., and Seibert, F. M., Methods and apparatus for the examination of mine gases and natural gas: Bull. 42, Bureau of Mines, in press.

TECHNICAL PAPER 26. Methods of determining the sulphur content of fuels, especially petroleum products, by I. C. Allen and I. W. Robertson. 1912. 13 pp., 1 fig.

TECHNICAL PAPER 32. The cementing process of excluding water from oil wells as practiced in California, by Ralph Arnold and V. R. Garfias. 1913. 12 pp., 1 fig.

TECHNICAL PAPER 36. The preparation of specifications for petroleum products, by I. C. Allen. 1913. 12 pp.

TECHNICAL PAPER 37. Heavy oil as fuel for internal-combustion engines, by I. C. Allen. 1913. 36 pp.

TECHNICAL PAPER 38. Wastes in the production and utilization of natural gas and means for their prevention, by Ralph Arnold and F. G. Clapp. 1913. 29 pp.

TECHNICAL PAPER 42. The prevention of waste of oil and gas from flowing wells in California, with a discussion of special methods used by J. A. Pollard, by Ralph Arnold and V. R. Garfias. 1913. 15 pp., 2 pls., 4 figs.

TECHNICAL PAPER 49. The flash point of oils; methods and apparatus for its determination, by I. C. Allen and A. S. Crossfield. 1913. 32 pp., 2 figs.

TECHNICAL PAPER 53. Proposed rules and regulations for the drilling of gas and oil wells, with comments thereon, by O. P. Hood and A. G. Heggem. 1913. 28 pp., 2 figs.

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